3RD SPACE EXPLORATION CONFERENCE & EXHIBIT

Robotic Missions to the Moon: Science & Exploration

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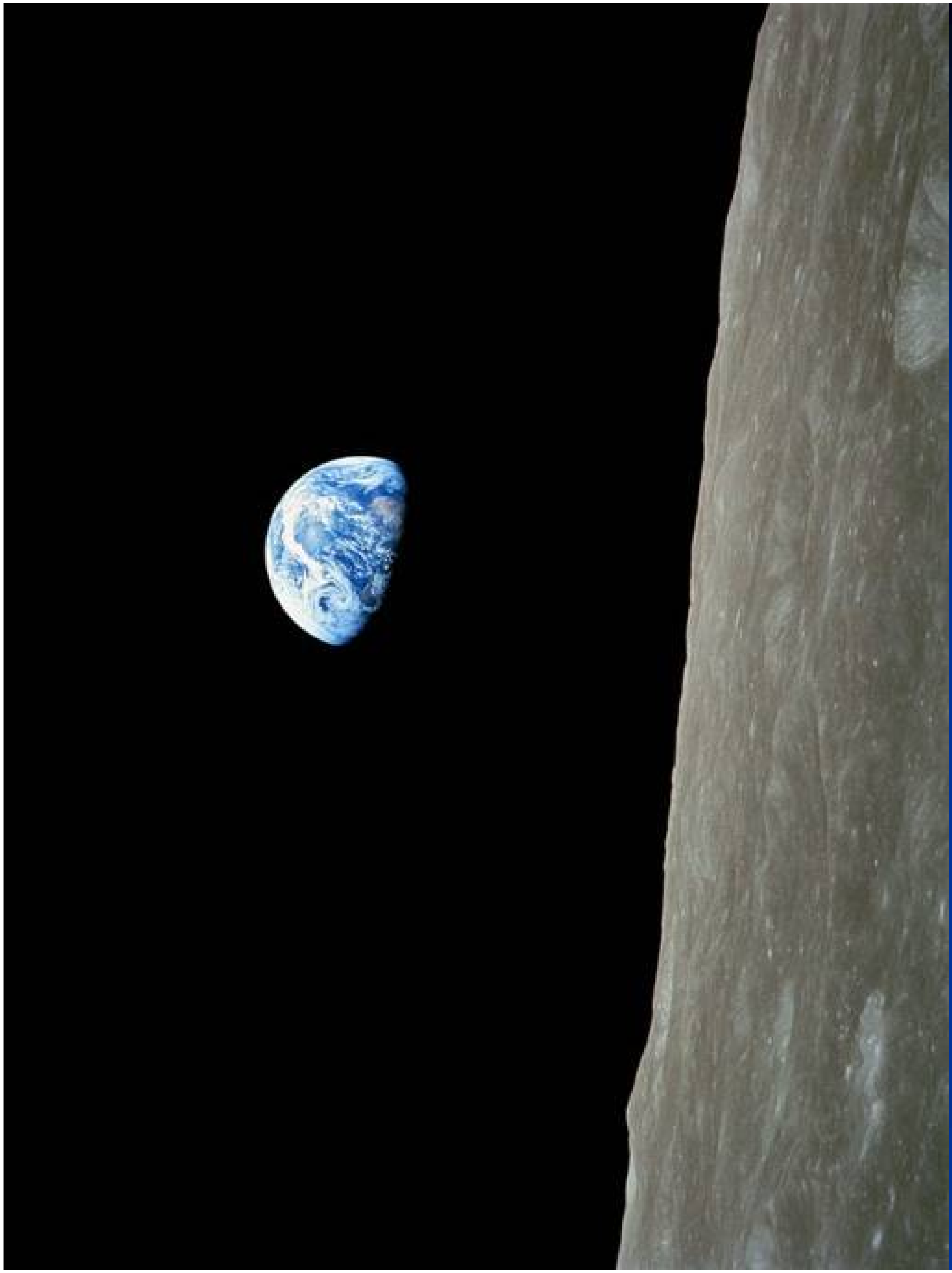


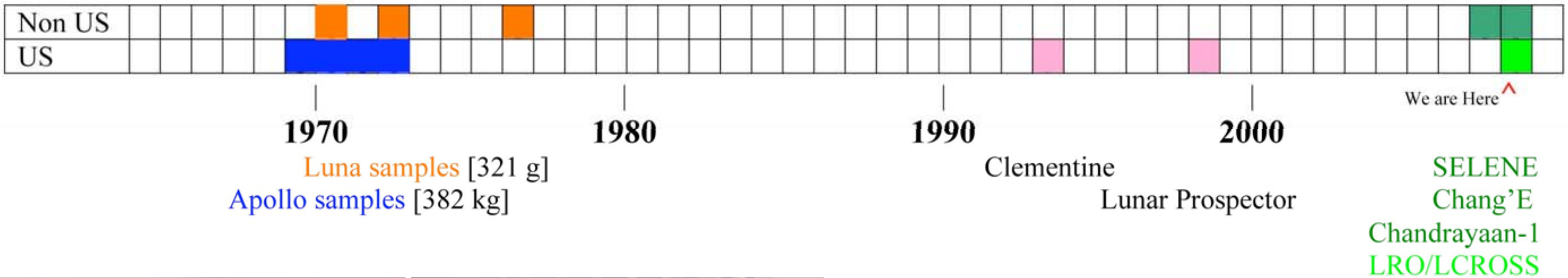
The NASA Vision for Space Exploration

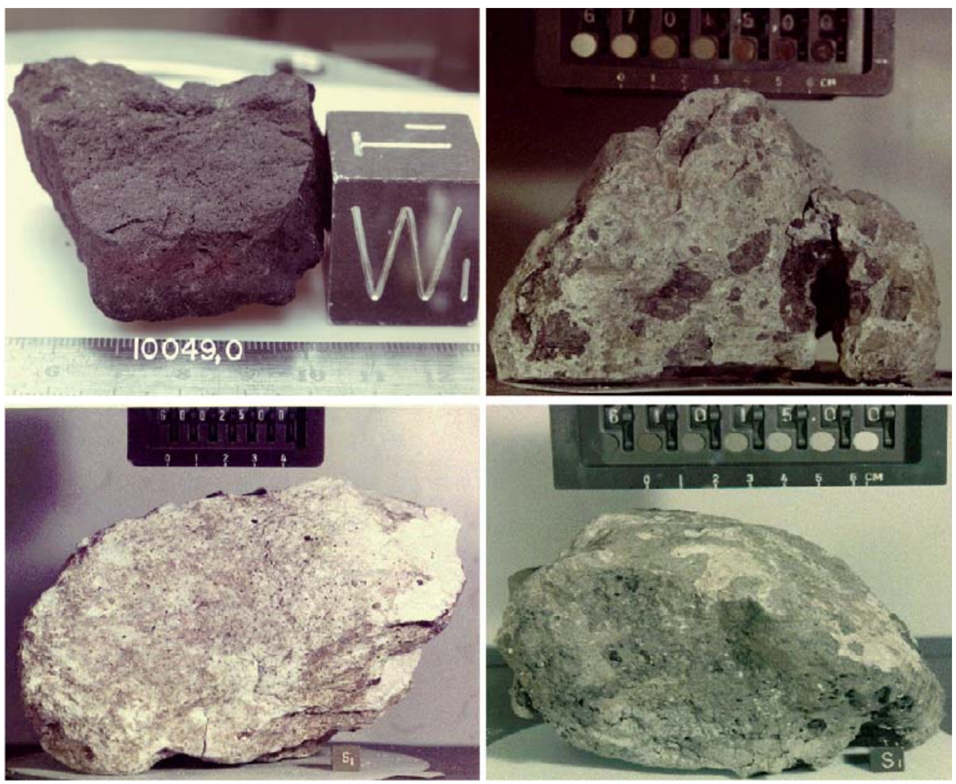
- The Moon is the first waypoint for human exploration beyond Earth:

  The Moon, Mars, and beyond.

- Robotic missions that will precede and support human exploration of the Moon offer opportunities to accomplish important scientific investigations about the Moon and the solar system beyond.

Lunar Exploration Timeline: Return after a long Drought





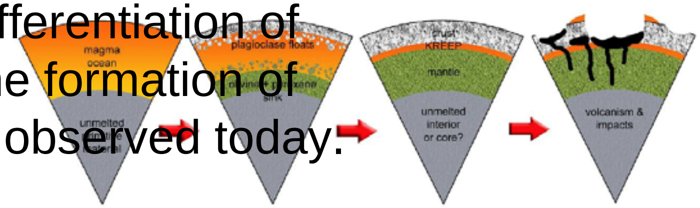
- The Apollo/Luna samples brought new and fundamental understanding of planetary evolution (and the Earth-Moon system).
- After decades of neglect, two very small missions were sent to the Moon. The small pulse of new data sparked several paradigm shifts.
- A fleet of sophisticated modern sensors are now *at last* exploring the Moon.

Post-Apollo Scientific Hypotheses

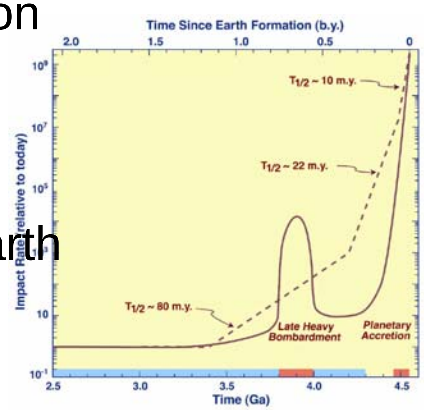
The context for understanding the origin and evolution of the Moon

- **The giant impact hypothesis**
  Explains the origin of the Moon as being assembled from debris after the impact of a Mars-sized object with the early Earth.

- **The lunar magma ocean hypothesis**
  Governs understanding of the formation of lunar rocks following lunar formation, and suggests that the outer portions of the Moon (several hundred kilometers in depth) were entirely molten. Differentiation of the vast magma body, a magma ocean, resulted in the formation of the earliest crust and mantle and produced the rocks observed today.



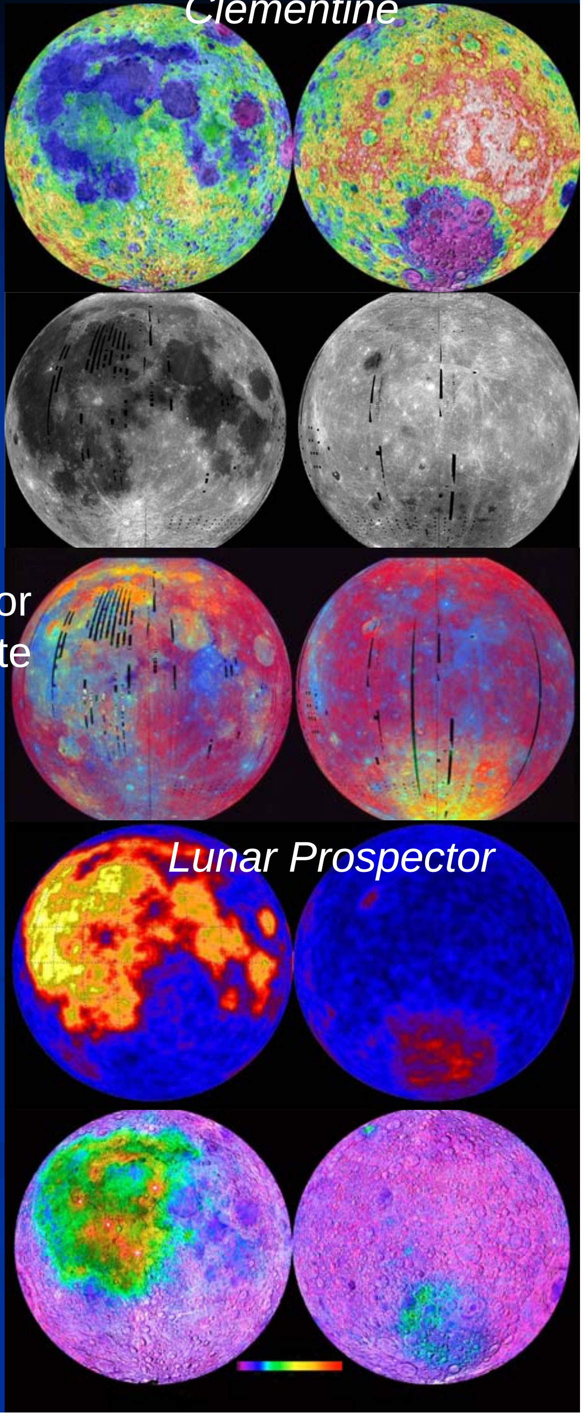
- **The terminal cataclysm (Late Heavy Bombardment) hypothesis**
  Concerns the timing of the impact flux in the 600 Ma after lunar formation. It proposes that the largest craters observed on the Moon (vast multi-ringed impact basins) were formed in a brief pulse of impacts of large objects near 4 Ga ago, well after impact-causing debris left over from solar system formation had died away. [An alternate hypothesis is that the rate of impacts to the Moon and Earth declined with time and no cataclysm occurred.]

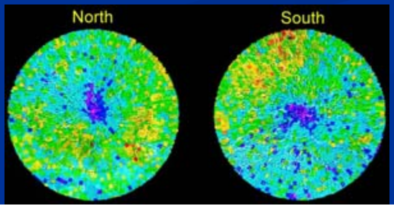


NAS/NRC 2007 Report

Paradigm Shifts from two small missions

- The enormous South-Pole Aitken basin dominates the feldspathic farside of the Moon.
  - Largest and oldest lunar basin
  - Minor basalt fill
  - Iron-rich interior (lower crust/mantle)
- Heat producing elements were concentrated on the lunar nearside (Apollo sites) early in lunar history.
- The poles are unusual environments and may accumulate volatiles.

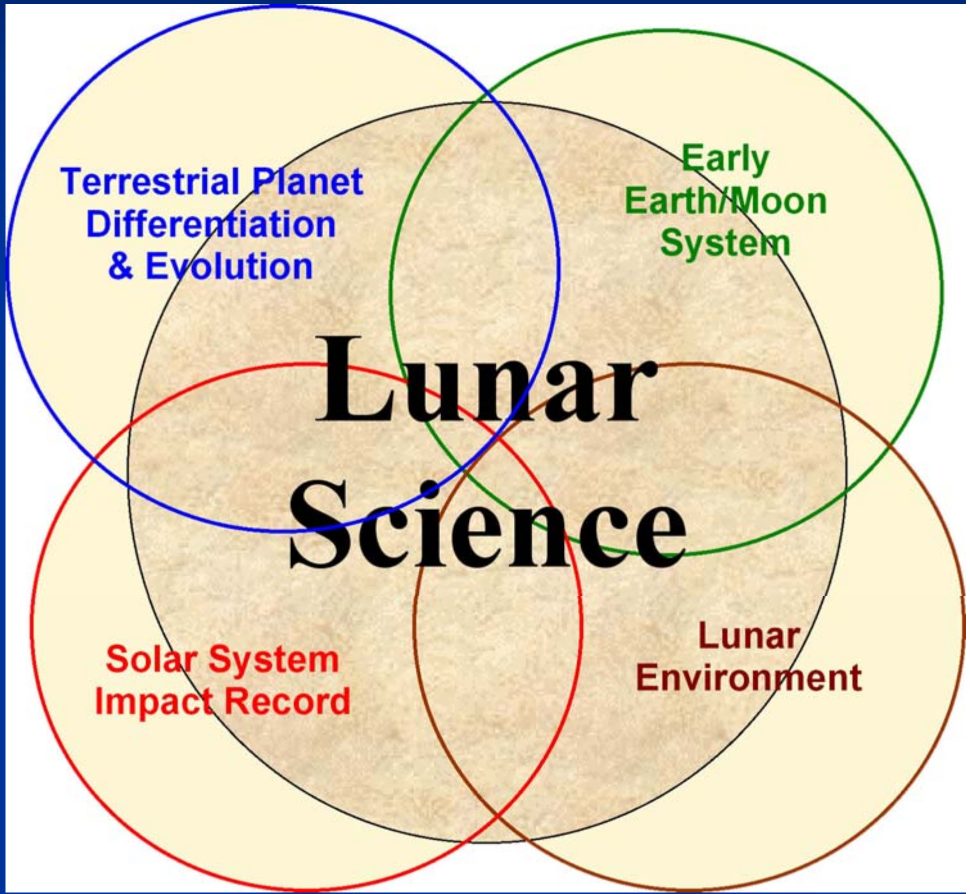




Why the Moon?

- The Moon is a *witness* to 4.5 billion years of solar system history.
- The Moon presents a record of planetary geologic processes in the purest form
  - Early crust evolution
  - Differentiation
  - Impact craters
  - Volcanic processes
  - Regolith processes and early Sun
- The Moon provides accessible unique environments
  - Polar regions
  - Exosphere (atmosphere)
  - Stable Platform

Overarching Science Themes



See NRC/NAS 2007 Report:

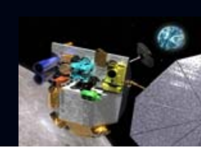
http://books.nap.edu/catalog.php?record_id=11954


International Lunar Exploration

	SELENE/KAGUYA [JAXA]	Chang'E [CNSA]	Chandrayaan1 [ISRO]	LRO [NASA]
Launch	2007	2007	2008	2008
Orbit	100 km polar circular	200 km polar circular	100 km polar circular	50 km polar circular
Objectives	Study lunar origin and evolution; develop technology for future lunar exploration	Surface structure, topography, composition; particle environment	Simultaneous composition and terrain mapping; demonstrate impact probe	Improve geodetic net; evaluate polar areas; study radiation environment
Payload	TC, MI, SP, relay satellites, X-ray, g-ray; laser altimeter; radar sounder, magnetometer, plasma imager	4-band micro-wave, IIM, X-ray, gamma-ray, WA stereo, energetic ions, laser altimeter	TMC, HySI, LLRI, HEX, Impact probe + *C1XS, SARA, SIR2, miniSAR, M3, RADOM*	LOLA, LROC, LAMP, *LEND*, CRaTER, Radiometer, [miniRF] **LCROSS**







Modern Remote Sensing Instruments at the Moon

Optical Sensors
Unique
*best of class:

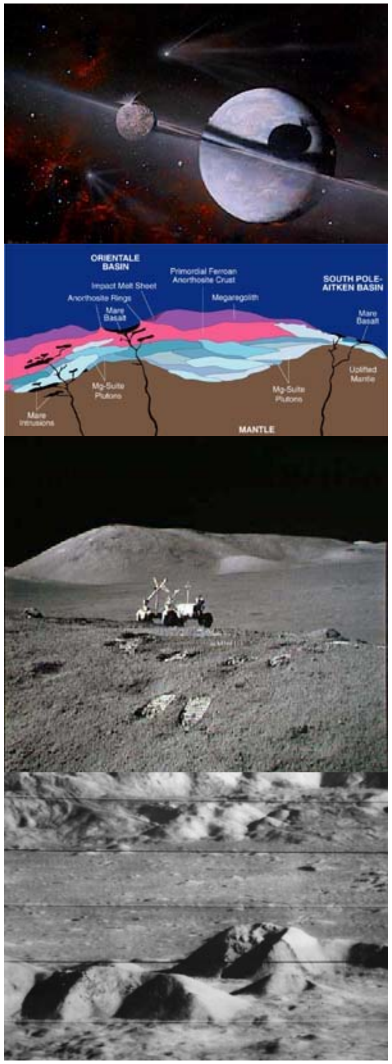
Instrument Type	**SELENE** [2007 JAXA]	**ChangÕE** [2007 CNSA]	**Chandrayaan**-1 [2008 ISRO]	**LRO** [2008 NASA]
Stereo imaging	TC	X	TMC*	
<1 m camera				**LROC**
Spectral camera	MI			(LROC)
VIS+ image spectrometer		IIM	HySI	
Near-IR point spectrometer	SP		SIR2	
Near-IR$^+$ image spectrometer			**M3**	
Laser altimeter	LALT	X	LLRI	LOLA*
X-ray Fl	XRS	X	C1XS, LEX	
γ-ray	GRS	X	HEX	
Neutron detector				LEND
Plasma/ions	CPS, PACE	X, X	RADOM, SARA	CRaTER
UV Imager				LAMP
Gravity relay	**RSAT**			
SAR			MiniSAR	MiniRF
Microwave sounder	LRS	Sounder **[4λ]**		
Radiometer				Diviner
Magnetometer	MAG/ER			
Other	HDTV		Impact Probe	LCROSS*
Planned Follow-on	Lander-rover	Lander; Sample return	Lander	Lunar base

Cumulative New Data for the Moon

- Detailed global elemental and mineralogical information in a spatial context.
- Detailed global topography, gravity, and geodesy.
- Primary understanding of polar environments.
- Detailed imagery (including stereo) at a variety of scales.
- Regolith sounding.
- ….and more!

What do we hope to learn?

- What is the early history of the Earth-Moon system?
- How does a small planetary body work? [thermal evolution; impact record; etc.]
- What processes have created and concentrated diverse materials on the Moon? Where are they? Why?
- What unimagined mysteries does the Moon hold?
- Where are the most productive places to do “field-work”?



International Opportunities Abound in this New Era of Lunar Exploration

- Collaboration
  - Release data to community
  - Invite participation
- Coordination
  - Optimize independent activities
  - Exchange information for planning
  - Cross-calibrate instruments
- Cooperation
  - Plan joint activities and strategy
  - Exchange experiments and personnel